A Diplexing Antenna System in Substrate Integrated Waveguide Technology

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***Abstract*—An inline substrate integrated waveguide (SIW) front end consisting of a diplexer and an antipodal tapered slot antenna (ATSA) is presented. The diplexer employs a dual-mode SIW cavity to establish the junction between filters and the antenna. The ATSA uses a Vivaldi profile and corrugations to enhance cross-polarization performance. A prototype is fabricated for operation at 23.7 GHz and 25.7 GHz, and measured results are in good agreement with simulations.**

I. Introduction

Over the past decade, substrate integrated waveguide (SIW) circuitry has developed into a mature technology that produced a large variety of mainly passive components. Although quite a few SIW diplexers and antennas have been developed, they have only been sparsely put together to form a diplexing antenna front end.

Some exceptions are presented in [1] and [2], where SIW slot radiators in one- or two-dimensional arrays are combined with inductive-iris-type SIW filters via an SIW T-junction. The direction of radiation is perpendicular to the substrate, and the T-junction requires transmitters and receivers to be located at opposite ends of the substrate.

This paper presents a more compact approach because it uses an inline system that has transmitter and receiver at one end of the substrate and the antenna on the opposite. Moreover, the antenna is an antipodal tapered slot antenna (ATSA) that radiates in the direction of the plane of the substrate. The junction between the ATSA and the diplexer is formed by a dual-mode resonator that adds one pole to each of the channel filters.

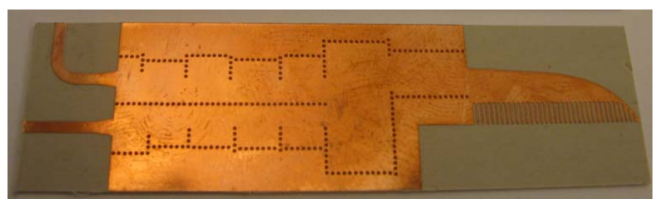
II. Design

Fig. 1 shows a photograph of the diplexing SIW antenna system. The unit is designed on RT/duroid 6002 substrate for operation at 23.7 GHz and 25.7 GHz with bandwidths of 1.4 GHz. The SIW widths at the Rx/Tx ports as well as at the ATSA are 5.4 mm. The via diameter is 1/64", and the via pitch is 0.6 mm.

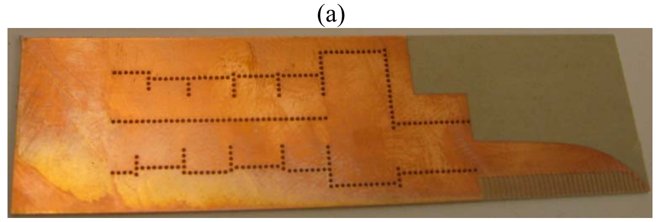
The design of the antenna is based on a parametric study presented in [3]. The substrate's permittivity is changed to that of the present design, and the taper and length of the ATSA are adjusted to the current frequency range. Moreover, while cut-outs of the substrate material towards the aperture are common in tapered slot antennas, this design was anticipated without such cut-outs, as in [4].

The design of the diplexer is carried out using a mode-matching technique (MMT) as outlined in [5, 6]. Having established the fact that 5th-order filters are required, the first step is to design 4th-order inductive-iris-type SIW channel filters, keeping in mind that the fifth-pole will be added by the dual-mode cavity, e.g. [7], that forms the junction between channel filters and antenna. This approach avoids a matching transition between the antenna and diplexer ports [8].

Once the dual-mode cavity is initially designed to support both TE_{102} and TE_{201} modes, the diplexer is optimized in the MMT for 5th-order channel characteristics. The performance of the entire system, including the diplexer and ATSA, is verified using CST.



(a)



(b)

Fig. 1. Photographs of the diplexing SIW antenna system; front (a), back (b).

III. Results

Fig. 2 shows a comparison between simulated and measured scattering parameters of the SIW diplexing antenna system. The maximum reflection coefficients are measured as -15.7 dB and -16.12 dB in the lower and higher bands, compared with -16.15 dB and -18.87 dB achieved in the simulation, respectively. The isolation between the Rx and Tx ports is measured as $|S_{32}|$=-23 dB, whereas the simulated value is -24.8 dB. The overall agreement between simulation and measurement data is good, which validates the design approach.

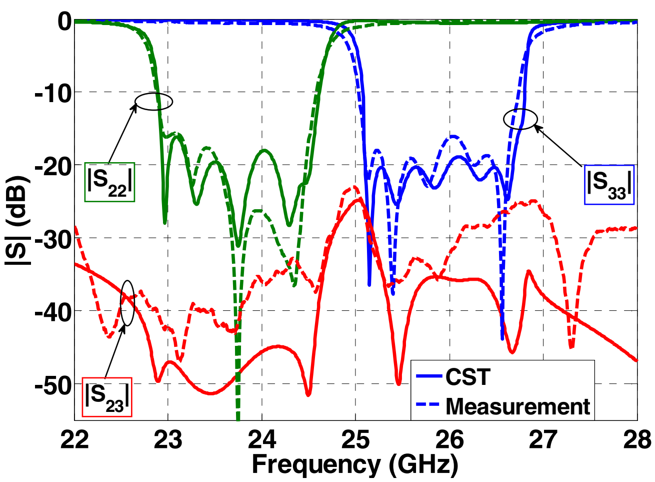


Fig. 2. Comparison between simulated (solid lines) scattering parameters with CST and measured data (dashed lines).

Measured and simulated radiation patterns in the two bands are shown in Fig. 3 and Fig. 4. Note that in both cases, slightly wider patterns are measured compared to the simulated ones. The agreement between the measured and simulated patterns in the lower channel at 24 GHz is good (Fig. 3). However, in the higher channel at 26 GHz, a ripple appeared at $\theta = -20^{o}$, which caused a higher value compared to that at $\theta = 0^{o}$. The discrepancies in the pattern measurements are attributed to the measurement setup in which the SIW antenna system was mounted within one half of a test fixture in order to access the respective ports. Due to these restrictions, cross-polar pattern measurements have not been conducted.

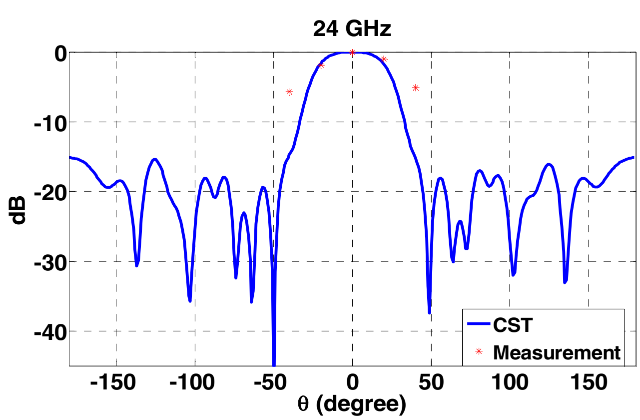


Fig. 3. Comparison between simulated (CST - solid line) and measured (asterisk) radiation patterns in the lower band at 24 GHz.

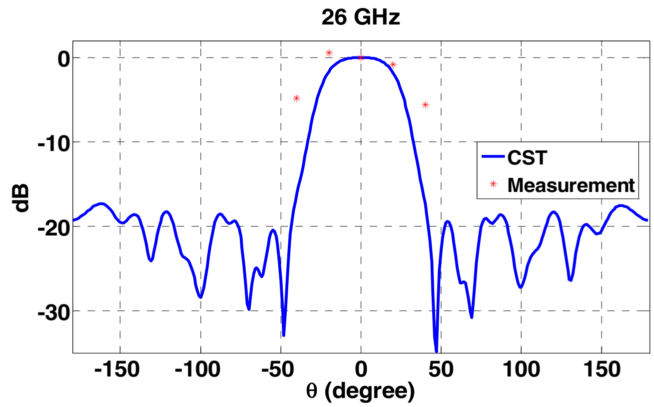


Fig. 4. Comparison between simulated (CST - solid line) and measured (asterisk) radiation patterns in the upper band at 26 GHz.

I. Conclusions

The SIW diplexing antenna front end presents a compact inline printed-circuit system that combines low-cost fabrication with good performance in the 23 GHz to 27 GHz range. The junction between the channel filters and the antenna is formed by a dual-mode resonator which adds to frequency selectivity and overall compactness of the design. Good agreement between measurements and simulations validate the design approach.

Acknowledgement

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